

MARICULTURE COMMITTEE

by

K. Tiewis

1979

BELGIUM

(G. Persoone and F. Redant)

During 1979 two pilot-scale operations have been built at the belgian coast for the nursery culturing of edible molluscs and the controlled mass culturing of the brine shrimp Artemia respectively. The goal of these semi-industrial constructions is to establish the cost-benefit of the operations on the basis of variation of a number of parameters which can be changed within the systems (f.ex. density, flow rate, temperature, food quality and quantity) and to extrapolate these results to a plant at the industrial scale.

The research programme on the pilot-scale nursery is carried out by the Laboratory for Mariculture at the State University of Ghent jointly with the Institute for Marine Scientific Research (IZWO).

The pilot-scale on Artemia production is taken care of by the Artemia Reference Center at the State University of Ghent, who also co-organized in August 1979 the "International Symposium on the brine shrimp Artemia" in Corpus Christi, Texas (USA).

The Artemia Reference Center further coordinates and actively participates in the so-called "International Study on Artemia", an interdisciplinary research programme of 4 USA and 2 European laboratories on the characterization and selection of Artemia strains for use in aquaculture.

The European Mariculture Society (registered Office at the Institute for Marine Scientific Research) besides its Quarterly Newsletters and Special Publications has issued a 550 pages book on "Cultivation of Fish Fry and its Live Food" (Proceedings of a Symposium held in Szymbark, Poland in September 1977).

At the Fisheries Research Station, Ostend, pilot-scale constructions are built for the stocking and cultivation of brown shrimp Crangon and North Sea sole Solea. A study on the propagation of the "black spot disease" of brown shrimp under selected and controlled environmental conditions was started in 1979.

Statistics (Belgium)

Species	tonnes
Flat oyster ( <u>Ostrea edulis</u> ) from culture beds	about 20

CANADA

(J. E. Stewart)

Atlantic Coast.

With the exception of the native oyster (*Crassostrea virginica*), the culture of marine species is very recent and in the early stages of commercial application or still in developmental or exploratory stages.

American Oyster. (*Crassostrea virginica*)

Oyster production continues to increase due to the development and application of improved technology despite continuing losses of growing areas due to pollution.

In Caraquet Bay, northern New Brunswick, a joint initiative by local fisherman's association and provincial and federal agencies has mounted a development programme involving the transfer of existing technology and development of new site-specific techniques. Major initiatives include the use of local shell in the development of natural seed areas, the use of suspended seed collection techniques and improvement of husbandry and management of the growing beds. Seed over-wintering techniques and predator control have emerged as important requirements.

In Cape Breton, Nova Scotia, raft suspended shell-string spat collection and bedding oyster production is well developed commercially and one grower has developed tray culture of market oysters into a viable commercial enterprise.

In Mainland Nova Scotia a provincial oyster hatchery is producing seed oysters for growers on the north coast in a feasibility study of the commercial potential of such seed production.

European Flat Oyster.

Descendants of the original 1969 introduction from the U.S., bred from quarantined brood stock, have been used to develop commercially applicable suspended culture techniques on the south, Atlantic coast of Nova Scotia. Commercial application is in very early development and will depend on a seed supply. To this end current studies are designed to evaluate and refine hatchery technology.

The gene pool of the original import is quite limited, though selective breeding has shown significant improvement in growth rates. Additional brood stocks have been imported from North America and Europe to increase the selection potential and allow further improvement particularly in the matter of cold tolerance. The F<sub>1</sub> generation is presently being held in quarantine.

Blue Mussel (Mytilus edulis).

The first commercial operations are now in production following the development and evaluation of production techniques in all four Atlantic Provinces. Technology, largely based on long-line suspension techniques, is adapted to the wide variation of local conditions, wave action, ice cover etc.

Bay Scallop (Aequipecten irradians).

In Prince Edward Island, a provincially sponsored programme is holding bay scallops from the U.S. in quarantine for introduction of the F<sub>2</sub> generation for evaluation of the potential for culture and establishment of self sustaining stocks. The F<sub>1</sub> generation, bred in 1979, suffered heavy winter mortalities apparently from generally toxic conditions in the restricted recirculation system. The survivors are now showing good growth. There are plans to import further broodstock in 1980 with emphasis on northern, cold hardy, stocks.

Sea Scallops (Pecten magellanicus).

A five year old programme investigating the potential for culture of the sea scallop has made significant progress. Laboratory rearing has achieved spawning year round but bacterial contamination of cultures makes spat production unreliable. Techniques for large scale field collection of spat have been developed and allowed investigation of culture techniques. Both suspended and bottom culture have been examined. Bottom culture appears most promising. A bioeconomic model has been developed to simulate and forecast the economic variables of rearing techniques with varying levels of spat fall. This performs well and has been used to design a pilot-scale test of the commercial viability of present technology.

Lobster (Homarus americanus).

Two approaches to lobster culture are underway,

1) a grow out operation involving the growing on of 200-300 g wild lobsters through one or two molts to 600-900 g, with a resultant gain both in weight and value per unit weight.

2) Complete culture from egg to adult.

A commercial company in Prince Edward Island is in the first year of a three year federal contract to evaluate and develop commercially applicable technology for both techniques.

There were significant advances in the experimental lobster rearing system in St. Andrews, New Brunswick. Developments included; a simple method for increasing survival of commercially impounded lobsters through cheliped modification and an inexpensive and efficient gas equilibration-skimming unit for pretreating culture water. Larval survival rates have been elevated to 50% from 5% or less, by improved husbandry. During the year cultured lobsters reached commercial size at 23 months of age and a survival rate from Stage IV of 66%. Information was obtained on growth rates of intact and eyestalk-ablated lobsters from hatching to market size, maturation rates in relation to temperature, development rates of male and female secondary sexual characteristics and environmental effects on reproduction cycles.



In continuing laboratory studies at Halifax, Nova Scotia of the potential of eye stalk ablation and subsequent growth enhancement in lobster culture, a doubling of past growth rates has been achieved by husbandry and dietary improvements. The achievement of a 450 g animal from the egg in twelve months would appear to be a reasonable expectation.

#### Rainbow trout (Salmo gairdneri).

Commercial marine culture in cages is now taking place in all four provinces. A private commercial operation in the low salinity waters of the Bras d'Or Lakes area is well established, marketing year round and is the major producer. Seasonal production of pan-sized (350 g) fish is general because of the high probability of lethal winter temperatures in most areas. The recent demonstration of a potential for over-wintering, in the the Bay of Fundy, provides new possibilities.

Relatively high losses in sea-cages, up to 50%, possibly largely due to vibriosis, is a serious constraint. Vaccines from local *Vibrio* strains are being compared with commercial products.

Stocks are largely obtained by importation of eggs or fingerlings. Development of self sufficiency and selection for local performance are highly desirable. The recent demonstration of significantly better growth performance of fry from eggs from sea-reared stock when compared to imported stocks has encouraged active pursuit of this goal.

#### Atlantic Salmon.

Under federal contract a private commercial operation is evaluating the salmonid rearing potential of a site at Deer Island in the Bay of Fundy. The site was chosen for a number of characteristics, protection from wave action, water exchange etc but especially its temperature regime, 0.5 to 12°C. Early results with Atlantic salmon are very promising. The first crop was marketed in 1979 at a mean weight of 3.3 kg after one sea winter, having shown good survival following some early losses probably due to acclimation and transportation shock. An important finding was that <1% of this stock was sexually mature in marked contrast to expectations. This is believed to be due to low levels of winter feeding.

This is a continuing study but has already led to widespread interest in the private commercial sector, with a consequent demand for a solution of a number of practical problems. These include, disease prevention, dietary requirements and cage design and investigation of the possibility of control of maturation through regulation of food intake in winter and spring.

Sea ranching studies at the St. Andrews, New Brunswick station are continuing. A weir for catching returning fish has been designed and built and works well. The best returns to date (>2%) have been from delayed release in 1976. The programme will continue with release of second generation smolts in 1980 and further investigation of delayed smolt released.

The improvement of feed used in smolt rearing is continuing. In preliminary experiments the lipid level appears to have a significant effect on protein utilization. Two salmon grower diets have been evaluated against an imported commercial feed. One performed well enough to be considered for local manufacture and use by federal hatcheries.

Reconditioning of kelts has great promise as a source of eggs, and experience in salt water has been quite satisfactory. In 1979 experience in reconditioning in freshwater showed great improvement, 40% survival compared to 12% earlier. This appears to be related to remedying vitamin and mineral deficiencies via dietary changes. A modified moist pellet resulted in improvements in weight gain and egg coloration, size and viability.

#### Pink Salmon (*Oncorhynchus gorbuscha*)

Because of its early adaptability to seawater and its rapid growth rate this Pacific species has been proposed for marine culture to pan-size and assessment of its potential for sea ranching. Results to date are indefinite. The species shows greater susceptibility to pathogens than native species. Overwintering stocks were lost early in 1979 when a cage was damaged. Stocks presently in cages in Bay of Fundy and Newfoundland waters are showing good winter survival.

#### Bluefin Tuna (*Thunnus thynnus*)

Commercial operations in one bay on the Atlantic coast of Nova Scotia hold large adult tuna caught incidentally to the mackerel fishery for seasonal fattening and fall slaughter for a gourmet Japanese market. Supplies of wild fish in 1979 were approximately one tenth of those of earlier years due to changes in the migration patterns, resulting in below normal production.

#### Pacific Coast

##### Oyster (*Crassostrea gigas*)

Spat fall was good in the major seed production area, Pendrell Sound. Some 210,000 strings, averaging 80 shells/string collected over 50 spat/shell.

Three quarters of the production of half shell oysters came from 10 operations using suspended, tray, culture, using local seed, largely from collection in the wild, plus a small hatchery component.

Mussel production is in early commercial development using long lines.

A private abalone hatchery was constructed in 1979 and will begin commercial production in 1980.

##### Salmon.

Eleven commercial operations are now licensed for cage culture of salmon, largely coho. Production dropped sharply in 1979 largely due to serious losses from furunculosis in one of the major operations. Demands for eggs in 1980 ( $5.5 \times 10^6$  Coho;  $0.6 \times 10^6$  Chinook) reflect the growing interest in such culture.

Experimental cage rearing at the Nanaimo Laboratory is continuing. Major areas of interest reflect the problems and potentials of the industry; inventory techniques; broodstock production; nutrition; disease control and selective breeding of coho and rainbow trout. Growth factors have been shown to have a high heritability in coho. A joint federal-provincial selective breeding programme is underway a major aim of which is the improvement of steelhead (sea run) rainbow trout. A number of strains are involved including recent introductions from Norway.

The potential of sea ranching of coho salmon is under investigation. In 1979 an estimated 2.5% of released smolts returned to the laboratory site as adults.

Blackcod (*Anoplopona fimbria*).

Considerable interest has developed in the cage culture of this species, shown in experimental work in past years to have a significant potential for culture. The proposed strategy is a feed-lot, grow-on operation, holding and growing wild caught yearlings to market size.

MARICULTURE PRODUCTION 1979

CANADA

(Complete statistics are not available, figures below are best available estimates).

ATLANTIC COAST

	<u>Metric Tons</u>	<u>Number (<math>\times 10^5</math>)</u>	<u>\$ (<math>\times 10^3</math>)</u>
Oyster, ( <i>C. virginica</i> ).			
Market (in shell)	1038	-	818
Seed (from vertical culture).	-	30	
Mussel ( <i>M. edulis</i> ) vertical culture	24	-	24
Rainbow Trout (less than 1 kg)	100	-	552
Atlantic Salmon	6.0	-	52
Tuna	-	56	N/A

PACIFIC COAST

	<u>Metric Tons</u>	<u>Number (<math>\times 10^5</math>)</u>
Oyster ( <i>C. gigas</i> ).		
For shucking (in shell).	2900	
For half shell.		4.8
Seed		(see text)
Mussel	2	
Coho Salmon	25 - 50	

DENMARK  
(E. Hoffmann)

The work with cultivation of turbot (Scophthalmus maximus) has continued in 1979.

The turbot cultivated in the laboratory in Charlottenlund will be transferred to experimental fish farms at powerplants in two differens areas in Denmark in spring 1980.

Research with the oyster Crassostrea gigas was started up in 1979. A few thousand spat oysters were imported from the institute in Langballigau and they were planted in the "Little Belt" and at a power plant in Kolding Fjord. High survival and extremely good growth was obtained during the year. The program continues in 1980 with the import of 100 000 spat oyster from Scotland.

The production of rainbow trouts (1.5-3.0 kg) in marine farms increased in 1979. The production is expected to increase steadily in the coming years.

Statistics (Denmark)

Species	Tonnes	Approx. No. in 100 000	Value in 1 000 U.S. Dollars
Flat oyster( <u>Ostrea edulis</u> ) from culture beds		5	500
Rainbow trout in enclosures			
less than 0.5 kg each	50		100
more than 0.5 kg each	100		500

Note: All figures are preliminary

Finland

(P. Tuunainen)

Mariculture in Finland has been developed along the following lines: production of rainbow trout (Salmo gairdneri) in net pens, research on production of salmon (Salmo salar) smolts in heated effluents, research on cultivation of brood stocks of salmon in fish farms using brackish water, and sea ranching of salmon, sea trout (Salmo trutta trutta) and migratory whitefish (Coregonus lavaretus).

Production of rainbow trout in 1978 was calculated on the basis of questionnaires carried out in 1979. Total production for markets was 808,5 tonnes<sub>2</sub> (3.4 million U.S. Dollars). In total, 32 fish farms with 243 net pens (87 900 m<sup>2</sup>) were responsible for this production. Production in brackish water was 25% of the total production (3 204,7 tonnes) of rainbow trout. An increase in production for 1979 is expected.

In 1975-1978 experiments on cultivation of salmon young in heated (about 10°C in winter) brackish water (6‰) effluents of a power plant were carried out. Because the result were promising, smoltification took place at an age of one year (in conventional cultivation at an age of 2 or 3 years) and at a size of 13-15 cm, plans have been made for greater production. Also experiments on cultivation of brood stocks of salmon in brackish water have been promising. The eggs produced by this way seem to be qualitatively closer to the eggs of wild stocks than those produced in freshwater fish farms.

To compensate for the losses caused by damming of spawning rivers of anadromous fish, cultivation of salmon sea trout and migratory whitefish young for stocking purposes has been in progress. Especially the responsibilities for stocking of these fish sentenced on the basis of water legislation in 1979 will increase the volume of sea ranching remarkably.

Statistics (Finland)

Species	Tonnes	Value in 1 000 U.S. Dollars
Rainbow trout in enclosures more than 0.5 kg each	808.5	3, 434.4

France

(J. Audouin et M. Guillaume)

Mollusques

Pectinidés : Expérience de captage

Pecten maximus :

Baie de St Brieuc - 50 000 collecteurs ont été immergés en Baie de St Brieuc, les résultats ont été médiocres (de 5 à 60 coquilles par collecteur).



Rade de Brest - 2 000 collecteurs ont été placés à proximité de l'Ile Longue. Les pontes intervenues entre avril et juin n'ont pas donné lieu à des fixations intéressantes (2 à 3 coquille par collecteur). Les travaux réalisés dans ces deux sites sont réalisés par des biologistes rattachés aux organismes professionnels locaux.

Belle Ile - Les essais ont été repris en 79 ; les collecteurs ont été immergés de juin à la fin août. Les meilleurs résultats ont été obtenus à la fin du mois d'août (80 coquilles par collecteur). (Travaux ISTPM).

### Clamys varia

Rade de Brest - 5 000 collecteurs ont été immergés en vue de capter des pétoncles noirs ; le dépouillement des résultats est en cours. Le captage serait de l'ordre de 500 à 1 000 pétoncles noirs par collecteur.

Baie de Quiberon - 4 500 collecteurs ont été placés au cours de l'été. Les meilleurs résultats ont été obtenus vers la mi-juillet (250 pétoncles par collecteur). La ponte principale s'est produite alors que la température de l'eau était inférieure à 15° : elle n'a été suivie d'aucun résultat.

### Vénéridés :

Les essais d'élevage en sol de la palourde européenne, Ruditapes decussatus et de la palourde japonaise, Ruditapes philippinarum se sont multipliés :

- en Bretagne Nord (travaux du CNEXO/COB)
- en Bretagne Sud (ISTPM - La Trinité/mer)
- dans les claires de Vendée (ISTPM Nantes)  
et de Charente (ISTPM La Tremblade)

Les essais d'élevage en sol, réalisés en milieu ouvert (ISTPM La Trinité) ont mis en évidence la nécessité de protéger les semis contre les crabes. Cette condition remplie, il est dès à présent possible d'envisager l'élevage de la palourde japonaise (taux de croissance et survie supérieurs à ceux de la palourde indigène). Les conditions optimales de l'élevage restent cependant à préciser (taille des jeunes palourdes au semis et densité initiale).

## Crustacés

### Homards :

La production de post-larves des Ecloseries a été la suivante en 1979 :

- Ecloserie de l'Ile d'Yeu (ISTPM) : plus de 150 000 post-larves et 1500 juvéniles.
- Ecloserie de l'Ile d'Houat : 55 000 post-larves et 7250 juvéniles.

L'étude comparative de la croissance en captivité du homard européen, du homard américain et des hybrides s'est poursuivie (ISTPM).

### Crevettes : *Penaeus japonicus* (CNEKO/COB)

Travaux de nutrition : les travaux ont porté cette année sur les besoins spécifiques de *Penaeus japonicus* en acides gras essentiels, en minéraux et glucides. On a testé en outre la possibilité d'incorporer dans les aliments des matières premières variées, protéines végétales en particulier.

Physiologie et écophysiologie : on a exploré l'influence de la température et de la salubrité sur le développement larvaire et on a commencé l'étude des effets du rythme nyctéméral : différents lots de crevettes sont élevés soit en nyctémères de 24h soit en nyctémères de 12h. Par ailleurs un travail sur les conséquences de l'ablation de l'un des deux pédoncles oculaires apporte des renseignements sur les mécanismes du déclenchement de la maturité sexuelle, obtenu par ce moyen.

Génétique : dans le but d'étudier la variabilité intraspécifique, une collection de souches en provenance de Hong Kong, Formose et Turquie est constituée

## Algues

Une étude a été entreprise par l'ISTPM en vue de définir les interactions entre les différents peuplements exploitables selon l'intensité de la récolte qui affecte les uns et les autres et de décrire les étapes du processus de repeuplement concernant *Ascophyllum nodosum*, *Fucus serratus*, *Laminaria digitata* et *Laminaria hyperborea*. Les travaux ont débuté en juin 1979 à l'ouest de l'Ile d'Er sur la pointe de Castel-Meur (Côtes du Nord). Des surfaces couvertes des espèces précitées ont été défrichées. La reconstitution des peuplements est suivie en comparaison de zones témoins. On s'oriente vers la production en masse de plantules de laminaires dans une des zones défrichées en vue de comparer le repeuplement de ce secteur et celui d'un secteur voisin où il n'y aura pas d'immersion de plantules.

### SALMONIDES

Les recherches ont surtout concerné l'aptitude à passer en mer, et plus spécialement l'évolution de l'ATPase  $\text{Na}^+ - \text{K}^+$  choisie comme critère de la smoltification.

Sur saumon argenté (*Oncorhynchus kisutch*), on a étudié la smoltification automnale. On a en outre comparé l'aptitude à passer en mer de *Salmo trutta*, *Salvelinus fontinalis*, *Salmo gairdneri* et de l'hybride *Salmo trutta* x *Salvelinus fontinalis*.

D'autres recherches ont été effectuées sur la reproduction des saumons : rôle de la corynébactériose dans les troubles de reproduction d'*Oncorhynchus kisutch*, reproduction de *Salmo salar* élevé en mer, alevinage de *Salmo salar*.

### BAR (*Dicentrarchus labrax*)

Les recherches ont surtout eu trait à l'étude des besoins en protéines et énergie, et à la relation entre composition corporelle d'une part, teneur de l'aliment en protéines et rationnement d'autre part.

### SOLE (*Solea solea*)

La mise au point des techniques de sevrage à différents âges a été poursuivie. De nouvelles formules alimentaires ont été recherchées.

### TURBOT (*Scophthalmus maximus*)

Les recherches ont concerné différents stades de la production : reproduction en captivité, techniques de sevrage, croissance, mise au point d'aliments adaptés à cette espèce.

### DIVERS

Le programme de recherches sur le décalage de la ponte par thermopériode et photopériode ou photopériode seule a été poursuivi, chez la sole, le turbot, le bar.

Il faut enfin mentionner les travaux sur la production d'algues et de zooplankton (simplification des techniques de production de *Brachionus plicatilis*, amélioration de sa valeur nutritive).

German Democratic Republic

(W. Loos)

In accordance with the guidelines drawn up in the previous year marine aquaculture research has been continued.

In a large-scale experiment on production of rainbow trout fingerlings in brackish water the results reached in 1978 were successfully repeated.

<u>Main data</u>	period	appr. 100 days
	fish weight-start	appr. 1 g
	-end	> 20 g
	feedconversion	> 2 g feed per g wet gain

The developed cage culture technology and technique was successful. The hexagonally shaped cages, feeding machines and further equipment met all requirements in moderately rough marine environment.

Small-scale experiment of rearing fry of rainbow trout in heated brackish water have been continued and are under study now.

Culturing of a rainbow trout stock resistant against diseases in brackish water has been pursued  
Experiments on oral immunization of rainbow trout fingerlings and fry against Vibriosis have been initiated.

Investigation of adaption of fry of Hypophthalmichthys molytrix and Aristichthys nobilis to brackish water has been continued. A start has been made on rearing fry in heated brackish water.

Beside engineering work linked with the above mentioned tasks a projekt of a pilot plant for utilization of heated brackish water of a power station has been drafted.

STATISTICAL INFORMATION ON MARICULTURE PRODUCTION

Mariculture production 1979  
German Democratic Republic

<u>Species</u>	<u>tons</u>
Rainbow trout in enclosures	
- less than 0,5 kg each	195
- more than 0,5 kg each	<u>17</u>
total	212
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Federal Republic of Germany

(K. Tiews)

Crassostrea gigas:

Indoor experiments on the reproduction and rearing of spat were continued as well as out door experiments on the fattening of spat to marketable sizes. The construction of the experimental station Langballigau near Flensburg of the Institut für Küsten- und Binnenfischerei was completed. 25 000 spat were produced.

Container culture experiments on various places along the German North Sea and Baltic coasts were also continued by the Institut für Küsten- und Binnenfischerei.

Fish nutrition:

Work was continued on the development of fish feeds for rainbow trouts in which fishmeal as protein source was substituted by other conventional and unconventional protein sources (Institut für Küsten- und Binnenfischerei). Also the development of eel feeds was continued by the same institute.

Work on production capacity of short artificial marine food chains consisting of phytoplankton - oysters and phytoplankton - zooplankton -fish (turbot) fry as well as work on optimising production processes and energy transfer by selected plankton species, by chemical and technological culture improvements, and by increasing the knowledge on the biology of selected species under culture conditions was carried out by the Institut für Meereskunde of the University of Kiel.

Rearing experiments of fish larvae in net cages suspended into eutrophic lakes and lightened by under water bulbs at night for zooplankton attraction were carried out by the same institute.



#### Cage farming experiments:

Cage farming experiments with rainbow trouts were carried out off the coast of Heiligenhafen, of Langballigau and of Eckernförde by the Institut für Küsten- und Binnenfischerei. Experiments on the early adaption of rainbow trout fry to brackish water conditions were made at the Institut für Meereskunde.

Experimental work on the rearing of salmonid fish in net cages suspended into brackish water of the cooling water outflow of an electric power station with emphasis on technical design of cages and supply boats, efficiency of food proteins as mussel flesh and krill, relationship of gas exchange at gill membranes and growth rates, load to the local ecosystem by intensive rearing of fish in the sea cages, was carried out at the Institut für Meereskunde.

#### Utilization of warm water effluents of power stations for Mariculture:

Apart from the work described in the above paragraph rearing experiments of Anquilla anquilla and Dicentrarchus labrax was continued at the experimental station Emden of the Institut für Küsten- und Binnenfischerei. Special emphasis was paid to develop silo technics for the mass rearing of elvers including the optimisation of feeds for these.

#### Recirculation sea water systems:

The biological station of Helgoland concentrated work on the optimisation of water quality management in brackish water recycling system, investigations on combined biological-chemical water treatment in intensive fish culture units. Also the Institut für Küsten- und Binnenfischerei continued its work on the development of a recirculating sea water system.

#### Sea ranching:

Sea ranching experiments with fingerlings of coregonids and rainbow trouts were carried out at the Institut für Meereskunde.

#### Fish culture:

Experiments on growth and reproduction of commercially important fishes of the North Sea and the Baltic as well as tests on the suitability of non-indigenous species for warm water aquaculture in temperate regions were continued at the Biologische Anstalt Helgoland.

Fish pathology:

Work to develop methods with which to describe stress conditions for fish in intensive aquaculture systems was continued at the Institut für Hydrobiologie und Fischereiwissenschaft of the University of Hamburg.

Physiology:

Cryopreservation experiments on long-term storage of sexual products of economically important species were continued at the Biologische Anstalt Helgoland.

Statistics (Federal Republic of Germany)

Species	Tonnes	Approx. No. in 100 000	Value in 1 000 U.S. Dollars
Blue mussels ( <u>Mytilus edulis</u> )	3 600	1	866
Pacific oyster ( <u>Crassostrea gigas</u> ) from vertical cultures seed-laboratory-reared	0.9		7 5
Rainbow trout in enclosures less than 0.5 kg each	1.6		5
Eel ( <u>Anguilla anguilla</u> ) not fresh water	4		30

ICELAND

(S. Einarsson)

Interest in fish farming in sea water is growing in Iceland, as in other countries. This is especially due to the good results obtained by the Norwegians.

Experiments with salmon farming in sea water are taking place in three localities in this country. The Fisheries Association has carried out experiments with salmon farming in net pens at Hafnir on Reykjanes. Private enterprises have also started similar experiments at Hafnir.

Dr. Sigurdur Helgason has during the past two years been conducting experiments with salmon farming in Grindavík (on Reykjanes). The method used is to pump warm sea water from a drillhole into tanks standing on the shore. Amongst others experiments in farming of salmonides takes place by using different temperatures and salinities.

The Fisheries Association has in past years conducted experiments with salmon farming in estuary Lake Lón in North Iceland. These experiments will be continued.

Private enterprise, Tungulax Ltd., producers of smolts, have entered into co-operation with the Norwegian salmon farming company Mowi. It is planned that these companies will form a company and carry out trials with salmon farming in the sea and ocean ranching.

A public shareholders company was recently established in this country under the name of Fiskeldi Ltd. This company intends to produce a great quantity of smolts and is planning to carry out experiments on a big scale with ocean ranching and salmon farming in the sea.

The Institute of Freshwater Fisheries has conducted salmon ranching experiments at Kollafjörður experimental fishfarm for fifteen years. Results are discussed in reports to the Anadromous and Catadromous Fish Committee.

Ireland

No report received.

NETHERLANDS

(Th. J. Tienstra and M. Fonds)

In 1979 no research in the field of mariculture has been carried out in the Netherlands. Mr. R. Dijkema finished his feasibility-study on the possibilities of mariculture in the Netherlands. This report may have some encouraging aspects for mariculture in the Netherlands, which will lead in 1980 or 1981 to some kind of mariculture research.

Statistics ( Netherlands)

Species	Tonnes	Value in 1 000 U.S. Dollars
Blue Mussel ( <u>Mytilus edulis</u> ) from culture beds	84 700	25 000
Flat oyster ( <u>Ostrea edulis</u> ) from culture beds	1 075	7 000

Norway

(D. Møller)

INTRODUCTION

The long-term projects concerning salmonids run by the Institute of Marine Research, Bergen, have been continued in accordance with the guidelines drawn up in previous years.

The experiments at the research stations, Akvakulturstasjonen Matre and Akvakulturstasjonen Austevoll, continued. Akvakulturstasjonen Matre is mainly concerned with rearing of salmonids in fresh and brackish water, while Akvakulturstasjonen Austevoll is equipped for salt water rearing of salmonids, for rearing of larvae of marine fish species, mussel farming and laboratory experiments on bioenergetics. Restrictions put on Akvakulturstasjonen Matre in connection with an outbreak of IPN virus in 1977, still had some influence on the activities at the station in the first part of 1979.

RESEARCH PROJECTS

Genetics.

Experiments with selective breeding of Atlantic salmon and rainbow trout have continued at the Institute of Marine Research. The field experiments are carried out at the research stations and at commercial fish farms.

The material belonging to this experiments was infected by IPN-virus in 1977. This material are reared to commercial food fish size at selected fish farms. Data are still collected, but this fish material cannot be used for producing an improved brood stock for fish farming because IPN virus are easily transferred by the eggs. New egg material are collected in 1977, 1978 and 1979, and this will be used as basis for improved brood stock.



Experiments on selective breeding are also conducted by the Agricultural University of Norway.

#### Behaviour.

Telemetric studies on behaviour of smolt of Atlantic salmon were continued in 1979.

Investigation of Atlantic salmon escapement from and bruising in monofilament and multifilament nets was carried out in a closed poll near Bergen. The study is part of a larger investigation of damage on the salmon stock of Norway. The Directorate of Game and Freshwater Fish and Institute of Marine Research cooperate on these experiments.

#### Pathology.

In 1979 the work has mainly been concerned with vaccination of farmed salmonids against vibriosis, and with pseudobranchial tumors in fish. Comparative studies on different types of vaccines and of vaccination were carried out. Virological studies on IPN virus were initiated.

#### Physiology and nutrition.

Comparative studies on various types of salmonid feeds (commercial dry food, moist pellets and wet feed) given to fish in sea cages were continued. Likewise experiments with use of binders in salmonid feed, with silage conservation of such feed and of shrimp wastes were continued.

Studies on lipoid liver degradation due to lack of Vitamine E and use of Calanus for pigmentation of salmonid fish were initiated. Also studies on use of shrimp wastes for salmonid feeding were initiated in 1979 in cooperation between Institute of Marine Research, Bergen, and the University of Tromsø.

Laboratory experiments of nutrition, digestion, growth, metabolism and energy budget of cod have continued, and the results are compared to results of in situ studies in net cages and tanks.

Experiments were also started to study the effect of smolt size on subsequent growth rate and age at sexual maturation. Likewise on subsequent growth rate in the sea for precocious males.

Studies on changes in the renin-angiotension-system during smoltification in Atlantic salmon were continued.

Feeding salmonid fry with sex-hormones to control later maturation was started in small scale experiments.

#### Rearing of marine fish larvae.

The experiments on hatching and rearing marine fish larvae and fry in land situated basins and in plastic bags in the sea, were continued. The main effort this year was put on the studies on concentration of natural food (Calanus larvae, etc.) in the plastic bags by filtration of large volumes of sea water. Utilization of closed polls for rearing cod larvae was planned for the 1980 season.

#### Other projects.

Experiments to assess the effectiveness of several antifouling compounds for net pens and rearing tanks were continued.

Experiments on commercial culture of mussels, Mytilus edulis, were continued. Especially technique for collecting larvae and geographical variation in larvae numbers were paid attention to in 1979.

Storage of live saithe in net pens for subsequent delivering to the fishing industry was continually studied. This year especially effects of stocking density, feeding of the saithe and healing of bruises were paid attention to.

Hydrographic and other environmental factors at the coast of the country of Hordaland were systematically investigated in order to map localities fit for farming of salmonids and storing of live saithe.

Development of technique for smolt rearing in net pens in fresh water was started by commercial fish farmers in 1978, and continued also in an experimental series run by the Institute of Marine Research in 1979.

#### STATISTICS

Quantities produced are given in the enclosed questionnaire. The main mariculture production in Norway still is rainbow trout and salmon. Concerning rainbow trout the public statistics give no breakdown on production in fresh and salt water, and the production in fresh water is not reported in the inland fisheries statistics. Thus the total production is given in the questionnaire. However, the quantities produced in fresh water is comparatively small, and 5-7% of the total production is indicated. Concerning other species no statistics exist, but small quantities of blue mussels and oysters were produced.

#### Statistics ((Norway)

Species	Tonnes	Value in 1 000 U.S. Dollars
Rainbow trout in enclosures more than 0.5 kg each	2 690	10 000
Salmon in enclosures	4 140	30 000

POLAND  
(B. Lubieniecki)

In 1979 experiments were continued on rainbow trout farming in Baltic water as follows:

- eggs were taken from the rainbow trout which remained in Baltic water for 2 years.
- incubation of rainbow trout eggs was carried out in brackish water
- particular attention was devoted to the problem of prophylaxis of vibrio diseases in the rainbow trout sea cage farming.

Statistics (Poland)

Species	tonnes
Rainbow trout in enclosures	
less than 0.5 kg each	30
more than 0.5 kg each	20
Other salmonids :	
Sea trout caught from stocking	100
Eel ( <u>Anguilla anguilla</u> ) caught from stocking	180

Portugal

No report received.

Spain

(M. Torre)

In Spain, in 1979, the research on flat oyster hatchery methods was continued and the spat was grown until commercial size by hanging culture. The method now looks ready to be applied on an industrial scale.

Some tests were also made on a hatchery scale with scallop (Pecten maximus).

A state-owned hatchery for flat oysters (Ostrea edulis) and clam (Venerupis decussata) began to obtain seed and spat. It is located in NW Spain where the shellfish cultures have a long tradition.

Some experiments were also made on cultures of bream (Chrysophrys auratus) and sea bass (Dicentrarchus labrax) with very promising results. As a consequence, there is a project to build up a state-owned marine fish farm on the Mediterranean coast of Spain.

In the southern Atlantic area of the Iberian peninsula (from the border with Portugal to Cadiz) the possibilities of using great salt pans for fish culture were tested.

In these salt pans, there is a natural production of Artemia salina cysts which is beginning to be exploited.

Also a commercial venture on Salmon (Salmo salar) cultured in sea water started to sell fish in the markets and the same company is carrying out research on Pacific salmon (Onchorynchus sp.).

Concerning seaweeds, some tests have been started by introducing small plants of Gelidium in the natural environment to follow the growth.

A certain number of laboratories and institutions continued research on other species on a laboratory scale (flatfish, shrimps, bi-valves, etc.).

Sweden

(B. Holmberg)

According to the Water Law about 2 millions of salmon smolts are stocked every year in the Baltic. In 1979 about 550 000 extra salmon and sea trout smolts were released. Sea-trout have been stocked in coastal areas with good results for the local commercial and sport fisheries. Short migrating strains of sea trout have been tested in certain areas. The most important task is to increase the survival of the smolts to increase the yield. The effects of smoltsize, time of releasing, adaptation to seawater and natural food are investigated.



Farming of rainbow trout for consumption have been tested in floating net cages in lakes and some coastal areas. It is not possible to culture fish in net cages during the winter on the Swedish west coast because of the low water temperatures. To eliminate this problem fish farming in recirculated systems have been analysed, specially by private companies.

The possibility of using brackish cooling water from nuclear power plants for fish farming are under investigation. Research programme: rearing technique for salmon, sea trout, rainbow trout and eel, growth and nutrition, diseases, testing the suitability of produced fish for stocking purposes or consumption.

A few pilot mussel farms are operating on the west coast. The ecological effect of musselculture was studied.

#### United Kingdom

(A.L.S. Munro) <sup>x)</sup>

#### ENDOCRINE STUDIES

Control of Sexual Maturation. Investigations have shown what had previously been inferred, namely, that hormonally produced all-female stocks of salmon, brook trout and rainbow trout reach sexual maturity later than untreated controls.

The back cross method of generating all-female stocks depends on the identification of genotypic females in the androgenised brood stock. A method has been devised which avoids the need to repeat this time-consuming process annually.

The effect of early treatment of fry with dietary 17-methyltestosterone on the adult levels of plasma androgens and its sterilising influence have been investigated.

Three processes for the production of sterile fish are under trial. These involve the immunological suppression of hypothalamic release hormones, their inhibition by exogenous steroids and the use of crude preparations of gonad antigens.

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<sup>x)</sup> The report comprises information from the Institute of Marine Biochemistry, Marine Laboratory and White Fish Authority.

Control of Ovulation. The recent development of a radioimmunoassay for  $17\alpha$ ,  $20\beta$ - dihydroxyprogesterone has revealed a surge in blood titres of this compound at the time of ovulation; its physiological role is being investigated. Work on the artificial induction of ovulation in sea-cage brood stock will be continued during this year.

Endocrine Rhythms. The detailed study of changes in endocrine status and in growth of salmon during their sea life has been continued. In females, as previously reported in males, endocrine levels indicate that the 'decision' to mature is made at least 10 months prior to spawning. A similar study of endocrine rhythms in sea-caged castrate and control rainbow trout is in progress and will reveal changes in extra-gonadal hormones. Comparative studies of the thyroidal status of farmed and wild salmon have been continued.

Parr-Smolt Transformation. The need to obtain detailed information on the endocrine status of wild fish to serve as a datum for farmed stock has resulted in the continuation of studies of parr and smolts in streams.

Environmental factors have been shown in wild pre-smolts to profoundly affect the function of the thyroidal system in a manner which is not manifested in the selectively stable environmental conditions imposed in farming practice. The effects of controlled environmental fluctuations on endocrine function and on the growth and smolting of parr are in hand. Smolting in both farmed and wild fish has also been shown to be associated with major disturbances of interrenal function, suggesting that an understanding of this process may enable a more rational management approach to the timing of transfer of smolts to sea water in relation to both their ability to osmoregulate in a hypertonic environment, and in relation to their loss of condition and impaired post-smolting performance.

## NUTRITION

Studies of the Effects of Ingestion of Peroxidized Fatty acid on Rainbow Trout  
Trout were fed on partially defined diets with adequate amounts of vitamin E and selenium containing an unsaturated fatty acid component consisting of either linolenic acid or a preparation of linolenic acid that had been oxidised under controlled conditions. On the diet containing the peroxidized fatty acid, trout showed a decreased growth and food conversion rate compared with the control in eight weeks. About half the peroxidized fatty acids was assimilated. The tissue levels of vitamin E and selenium were essentially

normal. In contrast subcellular fractions from the intestine of fish fed peroxidized fatty acids produced malonaldehyde when incubated in vitro in amounts significantly greater than the corresponding fraction from control. This difference may have early diagnostic value.

Mineral Metabolism. All trout in water containing 0.01 ppm manganese and fed diets containing 2 - 30 ppm manganese grew normally and showed no evidence of the pathological symptoms that have been previously ascribed to manganese deficiency in salmonids. The activity of various essential manganese requiring enzymes in tissues was not affected by the lowest level of manganese in the food. Copper intake over a range of 4 - 130 ppm in fish of 65 - 200 g wet weight had no influence on growth rate when copper to zinc ratios were maintained at 1:5.

Feed Attractants for Sole. It has been shown that the process of food selection and feeding behaviour in the Dover Sole (> 5 g weight) is induced by trace amounts of glycine betaine in the food. The chemical is a common tissue component in marine invertebrates and elasmobranch fishes but it is not present in teleosts. The specificity for glycine betaine is not absolute since juvenile sole (> 3 g weight) have an additional requirement for certain free L-amino acids. Large taste buds have been identified at the base of the villiform papillae and are presumably the sensory cells involved, since blockage of the anterior nostril did not abolish the ability of the intact fish to detect and eat a suitable food pellet.

Most but not all pelleted foods made up with these attractants are eaten by Dover Sole. For this and other reasons it is believed that some bulk protein preparations may also contain deterrents that inhibit the feeding behaviour of Dover Sole.

#### CULTIVATION

Turbot. Survival from egg to juvenile stages was very poor giving few fish for ongrowing trials for the following year. The cause is not known.

In ongrowing trials in sea water from a nuclear power station, turbot have been grown from 9.5 to 516 g mean weight in 280 days with a survival of 64%.

Sole. Survival from egg to juvenile stages was also poor in pilot scale experiments. Direct weaning from Artemia to inert diets was attempted but none of the 13 diets gave acceptable growth compared to Artemia or Lumbricillus control.

## DISEASE

Furunculosis. This bacterial disease, common in wild salmon and brown trout, has been a periodic problem in the short life of salmon farming in Scotland. It is prevalent prior to smolting and may cause serious loss in sea cage fish. Controversy has existed for 60 years over the varied pathology of the disease and about the pathogenic mechanisms possessed by the bacterium.

In 1979 we have shown that the pathogenic properties are contained mostly or wholly in extracellularly produced toxins which when injected into fish in the absence of the bacterium reproduce all the pathological features described in natural disease outbreaks. Our results indicate that individual organ pathology is dependent on bacterial growth and subsequent toxin production there, and that localisation in most organs is a random process. The prospects for basing a toxoid vaccine on the toxic extracellular products are the subject of further study.

Infectious Pancreatic Necrosis. The finding of significant pancreas pathology in virus positive post-smolt salmon has been disturbing especially in view of the poor growth performance of these fish. The origin of the virus in salmon is unknown.

Plankton Induced Mortalities. Four incidents occurred in sea pens which resulted in significant losses of salmonids. Two occurred in successive months at one sea loch and caused the death of all 1-sea-winter and older salmon but the post-smolt population suffered minimal detectable effects.

Phytoplankton are implicated but no conclusive proof exists. Pathology indicated intoxication but of a type untypical of known phytoplankton toxins. At a different site another incident during which significant numbers of Gyrodinium-like species were present resulted in deaths of a proportion of trout but few deaths in post-smolts. Little pathology was evident in moribund fish. Again the evidence for phytoplankton inducing the mortalities was circumstantial.

The final incident involved numerous jellyfish (Cyanea capillata) becoming entrained on the nets of salmon cages. In sufficient quantity their stinging tentacles are fatal for salmon. Subsequent to the jellyfish induced deaths many fish remained distressed for some time and an outbreak of furunculosis then occurred. The use of gill nets set some distance from pens has been proposed as a means of controlling the problem.

# ICHTHYOPHONUS

This systemic fungal parasite was found to be widely distributed in commercial fish stocks in Scottish waters. A localised area of heavy infection of haddock (up to 85% prevalence) and plaice (up to 14% prevalence) was identified in waters to the north of Scotland. Under experimental conditions the disease was shown to be highly pathogenic for plaice causing extensive loss of flesh weight similar to that found in commercial catches. It was concluded that significant mortalities in the commercial stock result from the disease. The disease is much less pathogenic in haddock but it causes extensive spoilage problems in processed fillets due to the subsequent germination of fungal cysts lodged in the flesh. An outbreak of the disease was recorded for the first time in a Scottish freshwater rainbow trout farm and was caused by feeding unpasteurised marine fish wastes.

## Statistics (Scotland)

Species	Tonnes	Value in 1 000 U.S. Dollars
Blue mussels ( <u>Mytilus edulis</u> ) from culture beds from vertical culture	not known	
Flat oysters ( <u>Ostrea edulis</u> ) from culture beds from vertical cultures	not known	
Pacific oyster ( <u>Crassostrea gigas</u> ) from culture beds from vertical culture	not known	
American oyster ( <u>Crassostrea virginica</u> )	not cultivated	
Common scallop ( <u>Pecten maximus</u> )	Experimental culture only	
Queen scallops ( <u>Chlamys varians</u> )	Not cultivated	
Lobster	Not cultivated	
Rainbow trout in enclosures Less than 0.5 kg each ) more than 0.5 kg each )	1 279	4 491
Salmon in enclosures	520	5 216
Other salmonids	None	
Eel ( <u>Anguilla anguilla</u> ) (not fresh water)	≥ 25	
Sole	Experimental	
Turbot	≥ 10	
Sea bass ( <u>Dicentrarchus</u> )	Not cultivated	
Others: Cod	≥ 2	

U.S.A.

(J.H. Ryther and A.C. Longwell)

Mariculture research in the United States is carried out at various universities and research organizations with support provided by the U.S. Office of Sea Grant and by the National Marine Fisheries Service at certain of their laboratories. These activities are summarized separately below. No information is available concerning mariculture research carried out by individual State, local or private organizations that is independently supported.

I. U.S. Office of Sea Grant-sponsored research

A. Finfish

1. Salmon

At the University of Alaska, researchers are examining the genetic interactions of Auke Creek hatchery-reared pink salmon with natural spawning stocks. In another project, the investigator is developing and testing an economical dry salmon ration comprised of readily available, locally-produced dry ingredients and a species of abundant, underutilized fresh fish. Also at the University of Alaska, researchers are determining the effects of oil-contaminated food on the growth of young pink salmon. The University of Alaska is establishing a training program which will produce hatchery technicians to work in the many new state and private salmon hatcheries. A unique part of this program is that a production hatchery is being established on campus which will produce fish for the common-property fishery and serve as a source of self-sustaining funds from the sale of returning salmon.

A major effort in salmon stock enhancement is being conducted at the University of Washington. This project is subdivided into the following four sections:

1. Development of management strategies for increased survival of wild and hatchery stocks of Puget Sound salmon based on alteration of behavior and quality of smolts.

2. Determination of the effects of various hatchery incubation systems on chum salmon fry quality and migration timing.

3. Development of an improved diet for young salmon.

4. Recovery and analysis of 1978 and 1979 adult salmon returns from experimental lots of coho and chinook marked and released in 1975, 1976, and 1977.

A major salmon pen rearing industry (DomSea Farms) has developed in Puget Sound. In an effort to help this industry, researchers are: 1) attempting to develop a coho salmon broodstock with desired characteristics for marine pen culture, and 2) looking at thyroid endocrine control of salmon smoltification to reduce parr-reversion.

Also at the University of Washington nutritionists and food scientists are attempting to develop nutritionally-balanced feeds that are readily acceptable, not only for young salmon but also for other larval fishes reared throughout the world.

Oregon State University has a diversity of salmon related projects covering the areas of research and training. Investigators are studying the interrelationships of dietary lipid and protein on the growth, quality and production of cold-water-cultured fish. In addition, researchers are attempting to bring back the Oregon chum salmon resources. Present objectives are: 1) to continue artificial propagations of Whisky Creek stock to accelerate development of an Oregon chum salmon brood stock, and 2) to develop and demonstrate a post-incubation strategy that maximizes return per unit of hatchery production.

University pathologists are: 1) providing an inspection service for Pacific Northwest aquaculturists that will facilitate their compliance with fish health regulations and their ability to maintain



healthy fish; and 2) improving techniques of immunization and developing new or more effective vaccines for the control of infectious diseases.

Agricultural and resource economists are: 1) gathering historical data on government regulations in the U.S. and abroad, and relating these data to historical development of aquaculture in different regions; and 2) analyzing production and cost relationships in various kinds of aquaculture to make possible predictions of how changes in these relationships affect the viability of aquacultural operations.

Because of the concern of industry with the effect of harbor seals as predators on salmon released in their ocean-ranching operations, researchers at Oregon State University are assessing the population growth and feeding characteristics of harbor seals to determine their current and future impact on aquaculture. Another project at OSU is concerned with public policy problems affecting the mix of wild salmon stocks, those cultured in public hatcheries, and those released into the ocean from private aquaculture.

Because of the expansion of aquaculture in the Pacific Northwest, there is a need for technical personnel capable of dealing with the complex interplay between disciplines - personnel prepared to act with proficiency in several specialized roles. To meet this demand, a program at Oregon State University, offers graduate-level opportunities for study in several aquaculture-oriented disciplines combined with opportunities for practical experience in salmon aquacultural production.

At the University of Idaho, a program is underway to abolish furunculosis and bacterial kidney disease in anadromous Pacific salmon.

As part of the University of California Sea Grant College Program, researchers at Humboldt State University are investigating the possibility of increasing chinook salmon returns by artificial

imprinting. At the University of California, Berkeley, researchers, by employing environmental or hormonal methods, are trying to alter the endocrine system and its control of salmon smoltification and sea water adaptation with the aim of reducing or eliminating initial mortality and subsequent stunting (parr-reversal) when young, incompletely smoltified coho salmon are transferred to sea water pens.

At the Universities of Maine and New Hampshire, studies are being conducted on the antigenic and genetic characterization of infectious pancreatic necrosis (IPN) virus of salmonids. Hopefully, the results will facilitate the development of an effective vaccine, and facilitate detection and identification of the virus.

A project related to Atlantic salmon is now underway at the University of Rhode Island. The objectives of the project are:

1. To minimize stress in salmonid production operations through environmental optimization, in order to reduce the incidence of infectious and non-infectious diseases.

2. To adapt European practices for the intensive culture of salmonids in acidic waters of low mineral content.

3. To establish a quantitative relationship between critical environmental parameters and blood factors affecting respiration.

In addition, URI economists are assessing the commercial viability of Atlantic salmon aquaculture in water reuse systems and ocean ranching in New England.

Supporting the salmon aquaculture program, URI pathologists routinely examine fish for diseases and suggest prevention and treatment.

## B. Crustacea

### 1. Penaeid shrimp

Research in penaeid shrimp is centered at Texas A&M University. For a number of years, investigators have been studying the

commercial feasibility of culturing this species in the U.S.

Emphasis has been directed towards production systems and determining which species can be grown successfully in ponds along the Texas coast. Jointly, with the National Marine Fisheries Service, researchers at Texas A&M and the University of Houston are attempting to increase their understanding of penaeid shrimp maturation and reproduction with the goal of being able to sexually mature and spawn a number of species in captivity. To back up this multidisciplinary program, economic data are being collected to improve models of commercial shrimp mariculture. Microbiologists are developing immunoprophylactic techniques for protecting shrimp against certain acute and chronic bacterial disease agents.

At the University of Arizona, investigators are examining the toxic effects of certain marine blue-green algae that have been circumstantially linked to disease in penaeid shrimp. Also jointly with San Diego State University, attempts are being made to develop an easily administered vaccine for Fusarium disease in shrimp.

## 2. Lobsters

A center for the development of the science and technology of crustacean aquaculture is now located at the University of California, Davis, and its marine laboratory at Bodega Bay. The objective of this program is to develop crustacean aquaculture by studying selected species and developing a technology that will lead to the domestication of these animals. In the past, the major effort has been made with the northern lobster (Homarus americanus), but the program is now being expanded to include other lobsters, shrimp and crabs. A multidisciplinary approach will be used to identify and solve problems common to crustacean aquaculture in reproduction, larval development, physiology, genetics, engineering, nutrition, and pathology.

A separate project at the University of California, Riverside, is directed towards an understanding of the basic mechanisms in-

volved in decopod fertilization and the development of methods for controlled fertilization of commercially important crustaceans, initially lobsters.

At Woods Hole Oceanographic Institution, investigators are evaluating the utilization of specific dietary components by post-larval lobsters in order to define an optimum protein:carbohydrate ratio and protein:energy ratio.

Scientists at the University of Maine are attempting to formulate and evaluate a minimum-cost lobster ration based on analysis of the lobsters natural diet and metabolism.

### 3. Brine shrimp

In a continuing project at the University of Rhode Island, investigators are examining 5 strains of brine shrimp in relation to their biochemical composition and ability to support survival and growth of marine fish and crabs.

## C. Molluscs

### 1. Oysters

Research at the University of Washington continues in the development of hybrid strains of oysters resistant to the summer mortalities that occur along the West Coast of the United States and in Japan. Selected hybrids have been placed in both areas where summer mortalities have occurred in the past. Results to date indicate that selected strains of hybrid oysters have improved resistance to summer mortality. Also at the University of Washington, the marine advisory service is attempting to determine possible causes of the reproductive failure of the Olympia oyster over the past two years.

At Oregon State, significant technological advances have been made in oyster culture. Presently, the investigators are encouraging commercial growers to adopt these new techniques. Specific objec-

tives include: (1) demonstration to growers of culture techniques for raising cultchless seed supplied by hatcheries; (2) a year-long experimental demonstration of selective breeding and brood stock management of Pacific oysters in a commercial hatchery; (3) identification of optimal conditions for producing Kumamoto seed oysters; (4) determination of the commercial potential of Crassostrea rivularis by evaluating methods of growing these oysters to market size; and (5) demonstration in Tillamook and Yaquina Bays of techniques for setting and growing-out eyed oyster larvae.

The largest major effort in oyster culture that is supported by Sea Grant is the development of a controlled mariculture system at the University of Delaware. The program includes many facets: nutrition, engineering, microbiology, and water quality. Several industries and government agencies are partners in this program. Presently, a \$1.2 million mariculture laboratory is being constructed. The major objective is to construct, continuously operate, evaluate and document a controlled-environment oyster production prototype system in the new laboratory. An important aspect of the project will be the development of a reliable technique for the mass cultivation of marine algae at a reasonable cost.

At Virginia Institute of Marine Science, studies continue on the development of oyster strains that are resistant to the disease Perkinsus marinus. These stocks, if developed, will be made available to hatcheries for the production of resistant seed.

At the University of Maryland, biologists are comparing the relative efficiency and cost-effectiveness of several "off-bottom" spat collecting techniques. The off-bottom technique is being compared to collectors placed on the bottom. Survival of newly collected oysters is being examined in protected environments.

A second project involves examination of larval populations in a shellfish hatchery to determine whether specific sub-classes of individual spawns have better development potential than others. In relation to stock enhancement, studies are underway to determine why certain rivers in the Chesapeake Bay have a good history of oyster setting while others do not. The results could assist managers to concentrate on conservation and/or rehabilitation of the oyster resources in regions with dispersive conditions that provide the best larval retention and spat settlement. Also at the University of Maryland nutritionists are attempting to determine the oyster's requirement for sterols.

Studies continue at SUNY/Cornell to develop methods to aid the shellfish industry with disease problems. A manual of shellfish pathology and a report on bacterial flora are in preparation.

## 2. Clams

Scientists at Oregon State University are developing methods for supplementing or rehabilitating natural clam resources through hatchery and planting programs. To achieve these goals, they are: (1) developing spawning methods for the cockle (Clinocardium corbus) and gaper clam (Tresus capax); (2) developing techniques to rear cockle and gaper clam larvae to planting size; (3) determining the planting time and clam size that will maximize field survival and growth to harvest size of several varieties of bay clams.

At the University of Washington, methods are being developed for large-scale application of plastic netting as an attractant for setting and for increasing survival of planted Manila clams.

Sea Grant is supporting two projects related to clam genetics. Scientists at George Mason University are studying the genetics and breeding characteristics of clams of the genus Mercenaria with the objective of developing breeding programs for producing superior strains and hybrids of these clams. At the University of Georgia,

protein gel electrophoresis is being used to mark genetically distinct strains of hard clams. This research will provide basic genetic data to facilitate stocking and management efforts for the clam fishery on the Georgia coast.

### 3. Abalone

The University of California, the California Department of Fish and Game, and private industry are together studying the technical and economic feasibility of enhancing abalone populations in depleted areas of southern California. These studies could establish the technological basis for seafloor farming of abalones by private enterprise.

Also in California, attempts are being made to develop a fundamental understanding of the remaining unknown biochemical and genetic control mechanisms governing the critical physiological process of metamorphosis, development and growth of abalone. An amino acid of algal origin (*L*-Aminobutyric acid or GABA) has been found to cause abalone larvae to settle and undergo behavioral and developmental metamorphosis.

A third project in California is directed towards interspecific hybridization in abalones in an attempt to produce strains with improved qualities for cultivation.

### 4. Scallops

Studies to refine hatchery and ocean-rearing methods for the purple-hinge rock scallop continue in California. The results of this project will hopefully establish procedures for commercial aquaculture of this shellfish.

### 5. Mussels

In order to determine the potential of commercial cultivation of mussels in Puget Sound, scientists at the University of Washington are comparing the intensity and timing of mussel larval recruitment



in selected areas of the Sound. Comparisons are being conducted between natural mussel setting with that observed on artificial substrates.

## II. Research at National Marine Fisheries Service laboratories

### A. Salmon mariculture research at the Northwest and Alaska Fisheries Center

A pilot study was undertaken to apply a series of sequential tests to determine the status of smoltification and fitness for survival of nine stocks of anadromous salmon from five Columbia River hatcheries. Four stocks of coho salmon, three of spring chinook salmon, and two of fall chinook salmon were examined for gill  $\text{Na}^+ - \text{K}^+$  ATPase activities up to time of release. Samples of the stocks were taken to Manchester (Washington) for introduction into seawater net-pens to determine long term (6 to 9 months) saltwater adaptability, growth, reversion to parr, and susceptibility to bacterial diseases.

In 1978, 25 hatchery stocks were examined. The studies included the incorporation of additional disease and physiological measures of fitness for ocean survival and the development of several new techniques and assays. The program is divided into four studies: status of smoltification in fresh water, sea water adaptation, disease, and development of short-term tests for determining adaptability to sea waters. By 1979 more than 90 hatchery groups had been examined.

Ongoing research in biochemical genetics continues. The present emphasis is based on the distinct capability of these methods for defining breeding units of natural populations and of estimating the contribution of defined units in population mixtures. Interest and activity persists in using genetic data as a management tool for identifying components of salmonid fisheries on the Columbia River. An orderly expansion of these efforts is envisioned to fisheries beyond the Columbia River.

A second major effort is focused on defining and classifying potentially threatened or endangered species or stocks of anadromous salmonids. Genetic data are needed to define distinct populations

and therefore are a necessary part of threatened or endangered classifications.

B. Mollusc research at the Milford, Conn. Shellfish Laboratory

1. Experimental inbreeding and hybridization

In one phase of an effort to research the effects of experimental inbreeding and hybridization in the commercial American oyster, Crassostrea virginica, several foundation crosses were made which provided full-sib families for establishing inbreeding lines. Some success was achieved in obtaining  $F_2$  full-sibs, though there was an indication of inbreeding depression in survival and growth when compared with outbred controls. Emphasis now is being placed on obtaining more lines of the  $F_2$  inbred progeny. An objective in establishing the inbred lines is to test-hybridize them for any manifestation of heterosis as successfully accomplished in the agricultural production of corn and poultry. Additionally, such homozygous lines could serve as uniform test systems for environmental studies.

To assess crossability and to investigate any expression of heterosis at other levels of hybridization, geographic and inter-specific hybrid studies have involved various populations and species in systematic crosses with local C. virginica. Some of the geographic hybrid crosses yielded offspring which were similar or intermediate to parental populations for survival and growth. Larvae from several of the inter-specific hybrid crosses have not survived as well. Cytogenetic examination and isozyme trials are supplementing the breeding research.

2. Selective breeding

Selection experiments for several traits of commercial importance in the American oyster, Crassostrea virginica, are currently being conducted. They include 2-way mass selection with a random control for juvenile growth rate, 2-way mass selection for

larval growth and setting rate, and 2-way family selection for meat yield. All experiments are in the first generation from selected parents. Preliminary results in the larval selection experiment seem to indicate that selecting the early setting larvae as brood-stock for the next generation does not increase larval growth rate but does increase juvenile growth rate in the early setting offspring. Early setting offspring from late setting parents were used as a control.

In conjunction with the selection projects, quantitative information on growth patterns and growth rate in the oyster is being collected. Such information is being utilized to improve the accuracy of the selection techniques and to maximize genetic gain in each generation. Results from studies show that size difference among young adult oysters does not yield growth rate differences in their larval offspring. Additional experiments have shown that oyster larvae that grow fastest and set earliest continue to grow fastest as young juvenile spat. However, between 7 and 18 months of age, this growth differential is lost. During this period, size differences between early and late setters become insignificant.

### 3. Spawning and rearing of mollusks

Work continues on methodologies for the controlled production of the bay scallop (Argopecten irradians) and the surf clam (Spisula solidissima). Enough progress has been made in the hatchery aspects of producing small juveniles of these species to allow emphasis this year on intermediate and final grow-out problems.

Encouraging results have been obtained in experiments utilizing vertically deployed cylindrical nets and rectangular cages for grow-out of hatchery-reared bay scallops in Long Island Sound. Survival was 80 to 90% in all experimental units. Growth rates of scallops were inversely proportional to stocking densities between 500 and 1500/m<sup>2</sup>; largest adductor muscle yield occurred at the greatest stock-

ing density. At least one more growing season is necessary before a thorough economic analysis of this system can be made but it appears that some potential exists for its commercial use.

Experimentation to compare the growth of hatchery-reared surf clams in a land-based, pumped raceway system with clams maintained in enclosures in Long Island Sound is underway. These divergent approaches to the production of potentially marketable 50 mm surf clams are being contrasted both biologically and economically. The seasonal growth of surf clams from a length of 18 to 50 mm was again demonstrated in the pumped raceway system. Ambient phytoplankton, the sole nutrition source, varied in abundance from previous years, yet the overall growth rates were comparable. Field plantings of hatchery-produced clam seed illustrated the high degree of predation encountered in Long Island Sound and the requirement of protective enclosures. Clams planted without protection burrowed in less than 24 hours; however, the mortality due to predation was nearly 100% after one week. The use of bottomless cages planted in the sand appears to be a promising method of predator control.

#### 4. Diseases of larval mollusks

In 1979 a monthly sampling cruise to Long Island Sound shellfish beds was initiated. Four hundred and fifty marine bacteria isolates have been collected, identified to genus, and bioassayed for pathogenicity to oyster larvae. Of these, 11 were found to be pathogenic to shellfish larvae.

Continued assistance to the shellfish industry included field studies and disease elimination at an oyster hatchery in California, as well as identification of beneficial organisms for a clam hatchery in New York.

Ozone detoxification of paralytic shellfish poison in living soft-shell clams was demonstrated in a field study in Maine.

In studies designed to improve the survival of cultured oyster larvae it was found that the potential for disease is much greater for larvae reared in natural sea water than for those reared in sea water passed through short-wave ultraviolet light.

Two of the five components comprising the prodiginine pigment of a pathogenic Pseudomonas sp. were found to be produced in quantities that are toxic to oyster embryos.

A number of in vitro cell handling techniques were developed; these are crucial to further studies of disease immunity in larval and adult oysters. The techniques included: 1) a method for isolation and microscopic study of larval oyster cells, 2) methods for developing and maintaining contamination-free larval cell cultures, 3) a method to prevent phagocytic cell loss on container walls as a result of extreme cell adhesiveness, and 4) definition of cellular physiological effects under various G forces during centrifugation. Using these techniques to examine cells of larval oysters exposed to pathogenic Vibrio spp., an immune defense reaction was observed in larvae as early as 2 days after egg fertilization.

##### 5. Aspects of nutritional requirements of mollusks

The successful rearing of mollusks for research or commercial purposes is dependent upon the production of large volumes of selected algal species that constitute molluscan food sources. The semi-continuous closed culture system for producing algal foods at Milford was designed to fulfill the following goals: culture containers must be economical to construct and simple to operate and maintain; the culture system must be free of all contact with metal and non-autoclavable plastic material, the system should accommodate simultaneously several different unicellular species that are axenic or close to it; the culture density should be high and the medium non-toxic to larvae. Following these precepts, 30 culture carboys are maintained daily to provide a harvest of larval and juvenile diets for mollusks reared at

the Milford Laboratory. This past year there was a harvest of 17,577 liters of larval, and 16,107 liters of juvenile algal foods.

In addition to pure algal cultures in a closed sterile system, open tanks containing 2000 liters of mixed algal species were cultured for the continuous feeding of spat and adult mollusks in the pilot-plant hatchery.

Experiments were conducted into the nutritional requirements of Crassostrea virginica veliger larvae in several different areas: 1) Algae that were growing in media with high concentration of the heavy metals copper and cadmium were tested as food sources for oyster veliger larvae. Algae apparently had concentrated enough metal intracellularly to induce poor growth and a high mortality in the grazing oyster population; 2) the nutritional value of several algae for which no information exists was tested. Feeding washed and unwashed cells of Chlorophyte No. 820 and Dicrateria sp. to unfed larvae yielded better larval growth with washed rather than unwashed cells. Feeding of No. 820 yielded larvae of similar size to those fed Isochrysis galbana, but feeding Dicrateria sp. was of considerable additional benefit to larval growth. In another approach to feeding studies, 6-day-old larvae were used for testing of a Tahitian isolate similar to I. galbana (Pseudoisochrysis paradoxa). This alga had no different effect on larval growth than the control (I. galbana) but larvae grew very poorly on the bacterized strain of the isolate; and 3) considerable experimental work was conducted to investigate utilization of a non-living food source, freeze-dried Isochrysis galbana, by C. virginica veliger larvae. Numerous experimental variables were examined, e.g., concentration of food particles, age of larvae, intervals between feeding, combinations of dried algae and soluble nutrients. Observations were made on the uptake and



digestion of living and dried food particles by bright-field and epifluorescence microscopy. The results of these observations indicate that living algal cells are far superior as a food than dried algae of the same species. It is interesting to note, however, that larvae fed with dried algae do show an active uptake and some digestion of these particles. There is also larval growth during the first few days of incubation but growth does not increase beyond a plateau value.

Annual U.S. Mariculture Production<sup>1</sup>  
(metric tons)

Pacific salmon	
pen reared	800
ocean ranching (public and private)	20 000 <sup>2</sup>
Penaeid shrimp	545
Molluscs	
oysters	9 273
hard clams (approx.) <sup>3</sup>	18
mussels	34

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<sup>1</sup>U.S. mariculture production statistics are not routinely reported or collected. Figures are most recent estimates as reported in the Draft National Aquaculture Plan of the U.S. Interagency Joint Subcommittee on Aquaculture; August, 1979.

<sup>2</sup>Very crude approximation based on estimated returns from hatchery reared releases, primarily public.

<sup>3</sup>Reported as 8000 bushels.



U.S.S.R.

(P.A. Moiseev)

Investigations on mariculture in the north-eastern Atlantic were carried out by the following institutes of the Ministry of Fisheries of the USSR : All-Union Research Institute of Marine Fisheries and Oceanography (VNIRO), Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Atlantic Research Institute of Marine Fisheries and Oceanography (AtlantNIRO), Baltic Research Institute of Marine Fisheries (BaltNIIRH) and several institutes of the Academy of Sciences of the USSR.

The following trends of investigations were developed: 1) artificial rearing of marine and diadromous fishes (in fenced-off areas of the sea); 2) commercial rearing of fish in sea water; 3) cultivation of food invertebrates; 4) cultivation of commercial algae; 5) acclimatisation of marine organisms.

1. Investigations aimed at the increase of the effectiveness of White Sea herring reproduction by the utilisation of artificial spawning grounds were continued.

The abundance of White Sea herring sharply decreased during the last two decades. At the same time, the food base of the White Sea allowed for considerably greater abundance of herring. Investigations of PINRO on the utilisation of artificial spawning substrates were commenced in 1976. The most suitable substrate (capron netting) was selected which provided the survival of 70-90% of eggs and hatching of considerable amounts of larvae. The complex of ecological parameters determining the location and spawning periods of herring was investigated. The areas for the location of spawning grounds were chosen.

The Murmansk Marine Biological Institute carried out experiments on the fecundity of capelin and plaice eggs. Young plaice were reared to 4,5 months.

BaltNIIRH and PINRO continued investigations aimed at increasing the effectiveness of artificial reproduction of Baltic salmon, the improvement of artificial foods and the technologic aspects of their production.

2. VNIRO continued to improve methods for market rearing of fish in sea cages. A light sea cage was designed. Methods of prevention and treatment of vibriosis in salmon were ascertained (together with BaltNIIRH). BaltNIIRH continued to rear coho salmon. Four year old males gained maturity while the bulk of females had underdeveloped ovaries with degenerative eggs. The survival rate of coho salmon in sea cages was higher than that of trout. Coho salmon was less susceptible to vibriosis but ran behind in growth rate under the conditions of the Baltic Sea.

AtlantNIRO continued to grow sturgeons (bester, beluga, Siberian sturgeon) in cages fed on small fish (stickleback, ruffe).

3. PINRO went on with the elaboration of methods for growing mussels in the Barents Sea and the Zoological Institute of the Academy of Sciences of the USSR in the White Sea. The Murmansk Marine Biological Institute carried out experiments on rearing Icelandic scallop in cages in water depths. Important work on cultivation of invertebrates in the USSR was in progress in the Black Sea and in the Pacific Ocean regions.

4. Experimental studies of algae cultivation were accomplished along with the elaboration of methods for rational exploitation of natural resources of commercial algae of the White Sea. Investigations of the cultivation of Laminaria and some agarophytes were in progress in the laboratory of algae of the PINRO northern branch. The cultivation of Laminaria was studied most carefully. In 1976-77 the possibility to cultivate Laminaria under the White Sea conditions was proved. At present the biotechnique of cultivating Laminaria

is being improved and the possibilities for shortening the period of growing are being investigated.

The development of gametophyte and early sporophyte of Laminaria saccharina in aquaria was studied in 1979. The main aim of these investigations was to find out the possibilities of growing Laminaria within one-year cycle. The first results of these investigations were obtained. All microscopic stages of Laminaria development were observed; from sinking of zoospore to early sporophyte. The investigations showed that viable zoospores were obtainable from Laminaria in the White Sea in spring, and viable sporophytes grew out of them. This fact allowed to assume that growing of Laminaria within one year cycle was possible in the White Sea.

The possibility to cultivate White Sea algae - agarophytes - continued to be considered. The cycles of development and growth rate of Ahnfeltia, Chondrus and Rhodomenia were being studied.

VNIRO, PINRO and Murmansk Marine Biological Institute carried out joint experiments on cultivation of Laminaria saccharina in the Barents Sea. The first good results have been obtained, the productivity of 20-30 kg by a gangion.

5. Investigations of the efficiency of natural reproduction of pink salmon acclimatised in the Barents Sea and the White Sea showed that in odd years the spawning of pink salmon occurred earlier and more effective than in even years. In all recent years, the delivery of eggs from the Far East continued. In order to clear out the reproduction efficiency of the local pink salmon population, it was agreed to stop delivering eggs in the coming odd years. In 1979, pink salmon eggs were not delivered.

The efficiency of the introduction of pink salmon in the Baltic Sea was low and the returns were very weak. The acclimatisation of north American striped bass in the Azov-Black Sea region continued. The progeny of the spawners reared in fresh water ponds was received in 1978 and 1979 and about 6 000 yearlings were reared. Some of them were released into the sea and others were reared in ponds to recruit the brood stock. Steelhead salmon introduced from the U.S.A. earlier were utilised for commercial rearing in a number of USSR regions. The best prospects for its cultivation were in the Black Sea.

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